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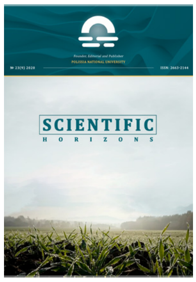

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Investigation of weight loss of napa cabbage depending on the type of packaging and head weight

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Abstract. The investigation of the issue of extending the period of consumption of fresh napa cabbage with different head weights due to the use of polymer films is relevant. The purpose of the study was to experimentally substantiate measures to extend the consumption of napa cabbage. The products were grown and stored on a farm. Studies with napa cabbage heads were conducted using the laboratory method and the method of mathematical statistics. It is established that napa cabbage loses up to 10% of its mass during storage for 20 days of storage. Individual packaging of heads in stretch film, in comparison with storage in open form, allowed for reducing the natural loss of their mass by half, increasing the storage period to 90 days. Among the hybrids examined, the best keeping properties were identified in a hybrid characterised by a high content of dry

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and dry soluble substances, vitamin C, and total sugar. When examining the shelf life of napa cabbage, depending on the weight of the head, it is identified that the stretch film extends the duration of storage of heads weighing 350-700 and 750-900 g to 70 days. Natural weight loss reaches 10.8%. Heads weighing more than 900 g with such packaging are stored for 90 days with natural losses of 8.8%. Inserts made of polyethylene film with a thickness of 40 microns extended the storage time of cabbage heads weighing 350-700 g to 80 days with a weight loss of 10.1%. Heads weighing 750-900 and more than 900 g were stored for 90 days with natural mass losses of 10 and 7.8%, respectively. Storage of a mixture of napa cabbage heads of different weights in the stretch film increased the storage period to 80 days, and in polyethylene film – to 90 days with a weight loss of about 10%. These results can be used by researchers in the trade industry to extend the storage period of fruits and vegetables

Keywords: fresh cabbage; head fractions; stretch filml; plastic film; shelf life

INTRODUCTION

Napa cabbage is an early-maturing crop that is suitable for growing in protected ground structures and long-term storage. Precocity, the rich chemical composition of the heads, and the ability to be stored for a long time make napa cabbage a valuable vegetable crop, which is successfully grown by Ukrainian producers in the open ground. Its presence in the diet contributes to the intake of fibre and essential minerals into the human body. The easiest and cheapest way to extend the storage period of fresh products is to pack them in polymer films. Therefore, investigation of the keeping properties of napa cabbage, depending on the type of packaging and the weight of the head, is relevant.

The modern assortment of this cabbage is represented by head hybrids of mainly foreign selection. Napa cabbage with elongated cylindrical heads is in demand among the population (Sun *et al.*, 2021). It has the aroma of fresh herbs, attractive colour, and a pleasant taste. Napa cabbage is high in sugar – 1.5-3.8%, contains up to 1 g of protein, 0.3 g of fat, 250 mg of potassium, 0.9-1.3 mg of iron, starch – up to 0.4, fibre – up to 0.7-1.2; calcium – 0.95, phosphorus – 1.16, potassium – 0.36, and sodium – 0.16%. The energy value of cabbage is low – 125 KJ/100 g (Zhou *et al.*, 2022).

Now consumers demand heads weighing 0.8-1.5 kg (Kovtuniuk *et al.,* 2020; Sadovska *et al.,* 2022; Dai *et al.,* 2019). Notably, the head of napa cabbage weighing from 350 g is considered standard (UNECE Standard FFV-44, 2017). The weight of the head depends on many factors: the characteristics of the hybrid, the cultivation technology, the weather conditions of the growing season, etc. Thus, napa cabbage of the Khibins'ka variety, in the studies of K.U. Holmamatovich (2021), due to various placement schemes, formed heads weighing from 0.62 to 1.24 kg. D. Paulus (2019) identified that with different soil moisture supply, weather conditions and hybrid characteristics, the weight of a napa cabbage head can vary by 5.5-27.5%. S. Teshome (2020) notes that a different fertiliser system leads to an increase in the head weight of this crop by 52.5%. In addition, during the period of mass maturation, a continuous harvest of napa cabbage is conducted and fluctuations in the mass of heads in the field can be substantial.

The high water content of napa cabbage heads creates the need for them to be stored in an environment with high relative humidity to prevent moisture evaporation. The presentation of vegetables depends on their loss of water during storage. It was identified that the maximum permissible water loss in white cabbage, potatoes, green peppers, and tomatoes is 7-8%; lettuce – 3-4%; strawberries, raspberries, currants, peas, and beans – 5-6%. Evaporation of water during storage depends on the characteristics of the variety, weather conditions of the growing season, and methods of harvesting and storage (Pusik *et al.,* 2019). Losses from water evaporation can account for 70-90% of natural losses (Ishaque *et al.,* 2019).

However, when storing napa cabbage, it is necessary to create a high relative humidity in the storage, which is not always possible. Practice shows that temperature fluctuations at high humidity in the storage area can lead to condensation on the surface of the product. Temperature fluctuations at high humidity in the storage area can lead to condensation on the surface of the product. Therefore, the evaporation of water during the storage of cabbage is inevitable. The choice of the method of storing napa cabbage with minimal loss of weight and quality remains relevant. Thus, conducting comprehensive research on factors that affect the natural weight loss of cabbage is relevant.

The main objective of the study was to compare the type of packaging and the weight of napa cabbage heads for weight loss during storage. Accordingly, the tasks were set to: establish the dynamics of natural mass losses, conduct a comparative assessment of the keeping properties of napa cabbage, depending on the type of packaging and head weight when using different hybrids.

MATERIALS AND METHODS

The study was conducted in 2019-2020 in the Agricultural Society "Mriya". It is located in the Lozivsky district of the Kharkiv region. Late-maturing napa cabbage hybrids Bazuko F_1, Bilko F_1, Suprin F_1 were examined Cabbage was grown according to generally accepted recommendations (Moiseichenko, 1992). Growing method – seedling (seedlings with four-five real leaves were planted). Seedlings were planted in a permanent place in the third decade of July. The method of placing plants is the strip row with a placement scheme (40+100)x20 cm. The density of plant placement is 71.4 thousand units/ha. Repetition in the experiment is fourfold. The area of the sown area is 50 m^2, accounting – 21 m^2. Napa cabbage was grown by drip irrigation. Soil moisture was maintained at 80%, the norm of one vegetative irrigation was 70-150 m^3/ha. The placement of options in the experiment is systematic.

Bazuko F_1 (Bejo Zaden) is a high-yielding hybrid of napa cabbage. The growing season lasts 70 days. Head weight is 1.2-1.8 kg. It is characterised by high resistance to many keel races. Created for long-term storage. Does not lose its fresh green colour (Bazuko F_1, n.d.).

Bilko F_1 (Bejo Zaden) is characterised by excellent taste qualities. The growing season lasts 67 days. Head weight is 1.2-1.8 kg. Created for long-term storage. The hybrid is resistant to many keel races (Bilko F_1, n.d.).

Suprin F_1 (Syngenta) is a hybrid of napa cabbage created for long-term storage. The growing season is 60-65 days, the average head weight is 1.5-2 kg, has a light green colour. This colour remains after long-term storage (Suprin F_1. Syngenta vegetable seed catalogue).

Cabbage was harvested by hand in a continuous way, weighed, and divided into marketable and non-marketable products. Marketable products were divided into standard and non-standard according to the current standard (UNECE Standard FFV-44, 2017). In standard products, the content of certain components of the chemical composition was determined according to generally accepted methods:

- dry substances – by drying (DSTU ISO 751:2004, 2005);
- mass fraction of dry solutes – by refractometric method (DSTU ISO 2173:2007, 2009);
- ascorbic acid – titrimetric method using 2,6-dichlorophenolindophenolate sodium (Naichenko & Zamorska, 2010);
- total content of sugars and reducing sugars-photocolorimetric (ferricyanide) method (DSTU 4954:2008);
- sucrose content was determined as the difference between the total sugar content and reducing sugars multiplied by a factor of 0.95.

The cabbage was placed vertically (with the top of the head up) in plastic boxes. After assembly, the heads were cooled to a temperature of 1-2°C. Napa cabbage was stored in a refrigerator at a temperature of 0±1°C and relative humidity of 90-95%, for one day in trifold repetition. Standard heads were stored weighing not less than 350 g. The weight of the average sample is 10 kg. Storage was conducted in accordance with the guidelines for conducting studies on the storage of vegetables (Naichenko & Zamorska, 2010). Product monitoring was conducted every 10 days.

Observation of napa cabbage during storage was conducted within two experiments. In the first experiment, napa cabbage was stored in an open form (control); in boxes lined with a polyethylene film with a thickness of 40 microns (PF), and packed in a stretch polyvinylchloride film with a thickness of 8 microns (SF). Before packaging, the cabbage was cooled to storage temperature to prevent condensation on the film and heads. The experiment is three-factor: factor A – type of packaging, factor B – duration of storage, and factor C – features of the hybrid.

The second experiment involved examining the preservation of napa cabbage depending on the mass of the head. The examination was conducted with the Bilko F_1 hybrid. Standard products were sorted into fractions: 350-700 g, 750-900 g, 950 g and more. A mix of heads weighing more than 350 g was taken for control, according to the standard. Cabbage was stored in open boxes (OB); in boxes lined with 40 microns thick polyethylene film (PF), and packed in 8-microns-thick polyvinylchloride stretch film (SF). The experiment is three-factor: factor A – head weight, factor B – type of packaging, and factor C – storage duration.

During storage, the dynamics of natural mass losses were determined. Natural mass loss was determined as a percentage of the initial mass by the formula (1):

$$X = \frac{(A-B)*100}{A}; \quad (1)$$

where X – weight loss, %; *A* – weight of heads before storage, g; *B* – mass of heads after storage, g.

The sample was withdrawn from storage if the weight loss was more than 10%, and no more than 10% of the products were affected by diseases and physiological disorders.

RESULTS

The formation of components of the chemical composition of vegetables depends on the characteristics of the variety, hybrid, and growing conditions, that is, the biological value is genetically determined. Dry substances – insoluble and water-soluble are an energy source of respiration of plants. Insoluble substances make up the cell walls and determine the toughness of the skin and pulp to mechanical influences. The consistency and colour of vegetables depend on the presence of insoluble dry substances. Soluble substances include mineral salts, water-soluble vitamins, sugars (di- and monosaccharides), etc. Vitamin C, also known as L-ascorbic acid, is a water-soluble vitamin that is naturally present in fruits and vegetables. Ascorbic acid is considered a stimulator of the formation of dense, heavy inflorescences and fruits. In addition, it shows antioxidant properties, protects against the harmful oxidative effects of free radicals and other substances. Ascorbic acid helps plants cope with the stresses of drought and ultraviolet radiation (Deslous *et al.,* 2021). Sugars are the main energy material. When sugar molecules are broken down and oxidised, energy is released that ensures the vital activity of the plant organism. Glucose is the main source of energy for cellular respiration (Eveland & Jackson, 2012).

Studies have established a substantially higher content of dry (LSD_{05}=0.1) and dry solutes (LSD_{05}=0.2), vitamin C (LSD_{05}=2.1), total sugar (LSD_{05}=0.2), and monosaccharides (LSD_{05}=0.3) in the hybrid heads Bilko F_1. The disaccharide content was 0.2-0.3% and there was no substantial difference between the hybrids (Table 1).

Table 1. *Content of some chemical components in napa cabbage heads (average for 2019-2020)*

Hybrid	Dry substances, %	Dry solutes, %	Vitamin C, mg/100 g	Total sugar, %	Monosaccharides, %	Disaccharides, %
Bazuko F_1	6.1	4.8	49.1	2.6	2.3	0.3
Bilko F_1	6.4	5.1	50.5	2.9	2.6	0.3
Suprin F_1	5.8	4.5	47.4	2.3	2.1	0.2
LSD_{05}	0.1	0.2	2.1	0.2	0.3	0.2

Source: *compiled by the authors based on their studies*

Notably, the accumulation of some components of the chemical composition, depending on the characteristics of the hybrid, ranged from 23 to 84%. The greatest dependence was observed between hybrid characteristics and dry substances (84%), total sugar (81%), and dry solutes (64%). Other factors and elements of the cultivation technology affect the content of chemical composition components within 1%. Correlation analysis showed that the weight loss of the heads during storage depends on the density of the heads and the components of the chemical composition (Table 2).

Table 2. *Correlation coefficient of weight loss of napa cabbage heads during storage from the density of heads and some components of chemical composition*

Indicators	y	x_1	x_2	x_3	x_4	x_5	x_6	x_7
Y	1	–	–	–	–	–	–	–
x_1	0.97463	1	–	–	–	–	–	–
x_2	0.90784	0.978664	1	–	–	–	–	–
x_3	0.90784	0.978664	1	1	–	–	–	–
x_4	0.92982	0.988602	0.998443	0.998443	1	–	–	–
x_5	0.90784	0.978664	1	1	0.998443	1	–	–
x_6	0.85375	0.948636	0.993399	0.993399	0.985453	0.993399	1	
x_7	0.99587	0.950281	0.866025	0.866025	0.89257	0.866025	0.802955	1

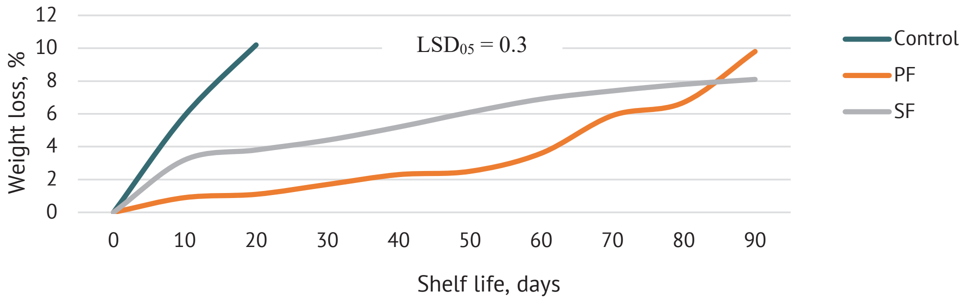
Note: *y – weight loss, %; x_1 – head density, x_2 – dry substances, x_3 – dry solutes, %, x_4 – vitamin C, mg/100 g, x_5 – total sugar, %, x_6 – monosaccharides, %, x_7 – disaccharides, %*
Source: *compiled by the authors based on their studies*

V.A. Koltunov (2004) identified that the shelf life of cabbage depends on the density of the heads. The density of heads is determined by the number of leaves per unit length of the head, the angular interval of their alternation, and thickness. It was identified that stale varieties of white cabbage have a head density of more than 0.8, and non-stale – in the range of 0.60-0.76.

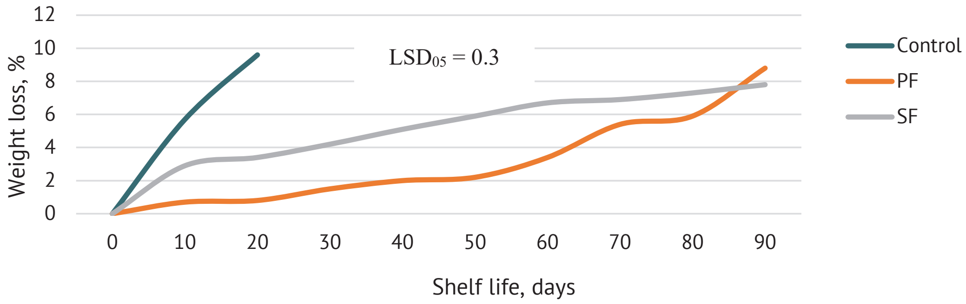
These studies have established that the density of napa cabbage heads ranges from 1.14 (Suprin F_1) to 1.36 (Bilko F_1). The head mass loss during storage is closely related to the head density (r=0.9746). The density of napa cabbage heads depends on the dry matter content (r=0.9786).

Regression analysis showed that daily weight loss depends on the content of dry solutes and on the density of heads: $y=10.2-30x_1+6x_2$. Where: Y – weight loss, %, x_1 – head density, x_2 – content of dry soluble substances. Thus, morphoanatomical and chemical indicators correlate with the shelf life of napa cabbage, so it can be concluded that the shelf life is determined by a complex of properties.

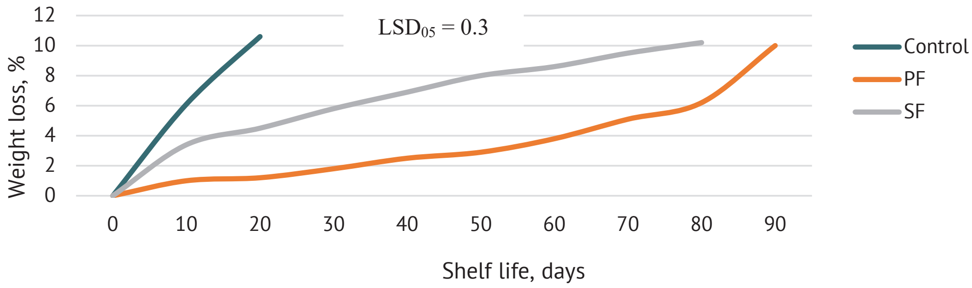
During the study of different types of packaging for the shelf life of napa cabbage, it was identified that storage without packaging already on the tenth day led to weight loss at the level of 5.7-6.1%, depending on the hybrid (Fig. 1). By the twentieth day, natural weight loss increased to 10.6%. The heads of the Suprin F_1 hybrid lost mass more intensively, and Bilko F_1 – less. Substantial difference (LSD_{05}=0.3) in terms of mass loss, on the tenth day of the storage, was only between these two hybrids. On the twentieth day of storage, all three hybrids differed substantially in natural mass loss.



a) Bazuko F_1



b) Bilko F_1



c) Suprin F_1

Figure 1. *Dynamics of weight loss of napa cabbage depending on the type of packaging, % (average for 2019-2020)*
Source: *compiled by the authors based on their studies*

The use of a 40-micron-thick polyethylene film on the tenth day of storage substantially reduced natural weight loss: it was almost six to eight times less than open storage. With further storage in a polyethylene film, natural losses gradually increased by 0.1 to almost 4% every 10 days. Notably, the Suprin F_1 hybrid lost more mass, and Bilko F_1 – less. Constant substantial weight losses were observed in experimental hybrids of napa cabbage from the 50th day of storage. On the 90th day of storage, natural weight loss reached 10% in the Suprin F_1 hybrid, slightly smaller it was in Bazuko F_1 – 9.8%, and substantially less (LSD_{05}=0.3) compared to the other hybrids – in Bilko F_1 – 8.8%. Notably, with this type of packaging, from the 80th to the 90th day of storage, there was a sharp increase in natural weight loss in all hybrids. Thus, if from the beginning of storage to the 80th day inclusive, natural weight loss every 10 days ranged from 0.1-2.3%, depending on the characteristics of the hybrid, then in the period from the 80th to the 90th day it amounted to 2.9-3.8%. This calls into question the feasibility of storing napa cabbage heads with this type of packaging for such a long time.

Packaging of napa cabbage heads in a stretch film with a thickness of 8 microns also substantially reduced (LSD_{05}=0.3) the intensity of natural mass loss. However, compared to polyethylene film, the intensity of mass loss was higher. Thus, on the tenth day of storage, napa cabbage heads stored in stretch film lost 2.9-3.4% of their weight. This is almost half as much for open storage, but four times as much for plastic wrap storage. During the entire storage period, mass loss for hybrids every ten days was substantial. However, on the 90th day of storage, the natural mass loss of Bazuko F_1 and Bilko F_1 hybrids stored in polyethylene film was substantially less – by 1.7 and 1.0%, respectively. While the Suprin F_1 hybrid had a ten days less duration of storage of heads in the stretch film than other hybrids. The natural weight loss of this hybrid for 80 days of storage was 10.2%.

It was identified that the natural weight loss of cabbage heads depends by 30% on the type of packaging (factor A), by 10% on the duration of storage (factor B), and by 10% on the characteristics of the hybrid (factor C). In addition, the combined effect of the type of packaging and shelf life – 40% – had an impact on natural weight loss.

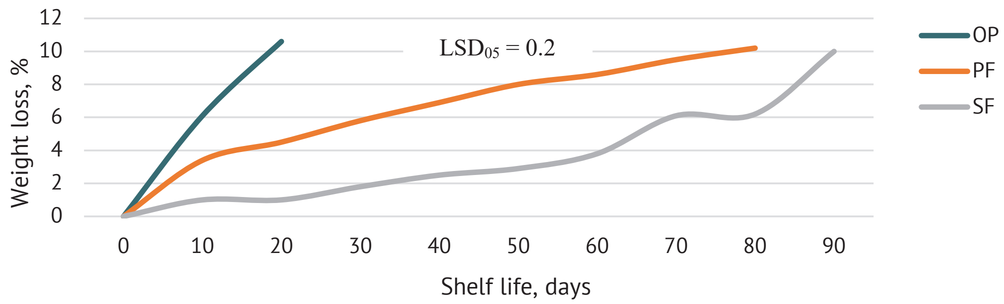
The correlation between weight loss, shelf life, and the packaging method of napa cabbage heads is determined. Under classical linear multiple regression, the coefficient (R) takes values from 0 to 1. It is assumed that the closer the coefficient is to 1, the better the model is. Therefore, it can be noted that there is a curved relationship between the weight loss of cabbage heads by the packaging method (Table 3). The coefficient of determination (R^2) is used as a model reliability marker.

Table 3. *Correlation of weight loss, shelf life, and packaging method for napa cabbage heads*

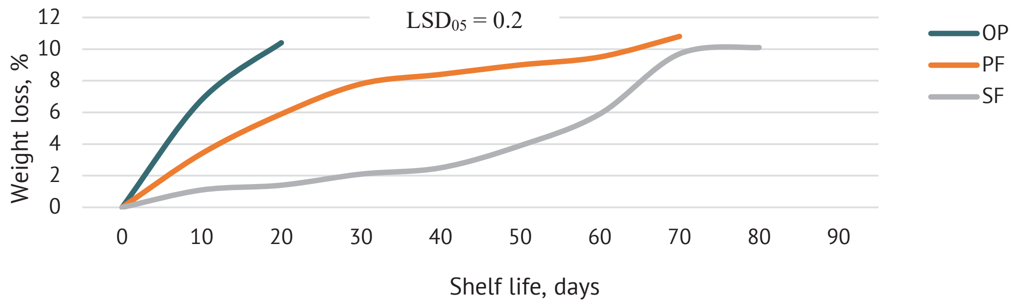
Option	Straight-line relation equation	R^2	Curvilinear relation equation	R^2
		Bazuko F_1		
1	Y=5.1x-4.833	0.99	Y=0.8 x^2+8.3 x-7.5	1.00
2	Y=0.959 x-1.827	0.88	Y=0.121 x^2-0.369 x + 0.832	0.97
3	Y=0.797 x+0.907	0.92	Y=0.075 x^2+1.618 x-0.735	0.97
		Bilko F_1		
1	Y= 4.8 x-4.5	0.99	Y=-0.9 x^2+8.4 x-7.5	1.00
2	Y=0.873 x-1.733	0.89	Y=0.1072 x^2-0.306 x + 0.625	0.97
3	Y=0.769 x+0.793	0.92	Y=-0.075 x^2+1.594 x-0.857	0.97
		Suprin F_1		
1	Y=5.3 x-5.03	0.99	Y=-0.8 x^2+8.5 x-7.7	1.00
2	Y=0.955 x-1.72	0.88	Y=0.109 x^2-0.249 x + 0.688	0.96
3	Y=1.158 x + 0.531	0.94	Y=-0.109 x^2+2.257-1.483	0.99

Note: *1 – open box (control); 2 – box + film 40 microns; 3 – stretch film 8 microns; x – duration of storage, days*
Source: *compiled by the authors based on their studies*

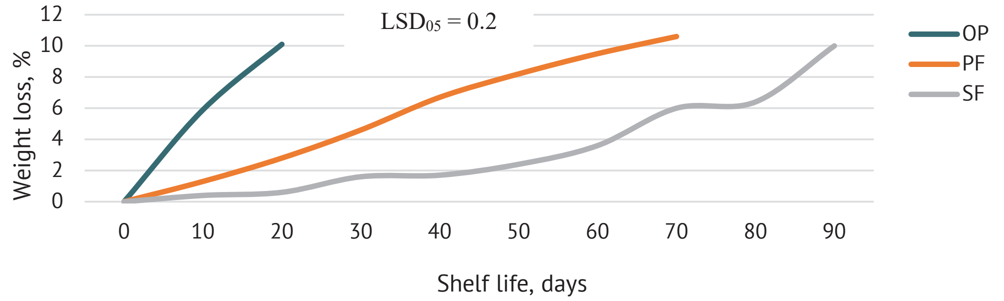
Thus, the use of packaging made of polyethylene film with a thickness of 40 microns and stretch film with a thickness of 8 microns helps to extend the shelf life and reduces the natural weight loss of napa cabbage heads. Natural mass loss is reduced by creating a passive modified gas medium (MGS) around the product. In MGS, the intensity of respiration of fresh fruits and vegetables slows down, and the enzymatic decomposition of respiratory substrates is delayed. In addition, MGS substantially suppresses the spoilage of products by microorganisms, since the increased content of CO_2 has an antimicrobial effect (Caleb *et al.,* 2013). When storing various fractions of napa cabbage heads, natural mass loss during storage in an open box was substantial (LSD_{05}=0.2) within 20 days (Fig. 2). On the 10th day of storage, natural weight loss was 5.7-6.8%, and on the 20th day, it reached 9.6-10.6%. The heads weighing more than 900 g were characterised by the lowest mass loss. As the head mass decreased, natural loss increased. A mix of napa cabbage heads of different weights lost 6.1% of the mass on the 10th day of storage, 0.2% more than heads weighing 750-900 g, and 0.7% less than heads weighing 350-700 g. On the 20th day of storage, the natural mass loss of the head mix in an open box was substantially higher compared to all the other storage options – 10.6%.



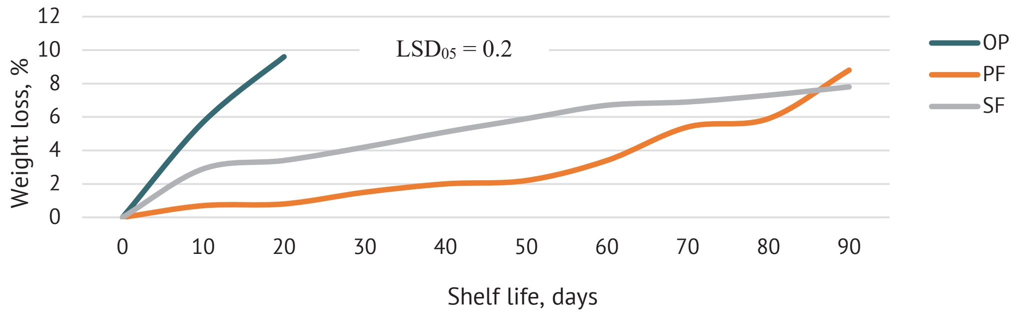
a) Mixture of heads weighing at least 350 g (control)



b) Heads weighing 350-700 g



c) Heads weighing 750-900 g



d) Heads weighing more than 900 g

Figure 2. *Dynamics of weight loss of napa cabbage depending on the head weight, % (average for 2019-2020)*
Source: *compiled by the authors based on their studies.*

Packaging of napa cabbage heads in stretch film contributed to a substantial (LSD_{05}=0.2) reduction of natural mass loss in all fractions. Thus, on the 10th day of storage in variants with a mix of heads and with heads weighing 350-700 g, the mass loss was two times less than for storage in an open box. In the version with a head mass of 750-900 g, loss decreased by 4.5 times, and in the version with a head mass of more than 900 g – by eight times. There is also a tendency to reduce natural weight loss due to an increase in the mass of cabbage heads. With further storage in stretch film, the shelf life of the head mix increased to 80 days and natural weight loss during this time amounted to 10.2%. Heads weighing 350-700 g and 750-900 g were stored for 70 days and weight loss during this period was 10.8 and 10.6%, respectively. The difference in natural mass loss over the entire storage period, both between these two variants and within each of these variants, was substantial.

Heads weighing more than 900 g in the stretch film were stored for 90 days without loss of quality. Starting from the 20th day, the difference in weight loss for every 10 days of storage increased substantially and on the 90th day amounted to 8.8%. Storage of a mix of napa cabbage heads in a polyethylene film increased the shelf life, compared to packaging in a stretch film, by 10 days. During 90 days of storage, natural weight loss was substantially (LSD_{05}=0.2) lower and amounted to 10%.

Heads weighing 350-700 g in polyethylene film were also stored for 10 days longer with substantially lower loss than during storage in the stretch film – 10.1% for 80 days. The polyethylene film extended the shelf life of cabbage heads weighing 750-900 g by 20 days. Therewith, for 90 days of storage, natural mass loss in this variant was 0.6% less than for storage in stretch film for 70 days – 10%. Heads weighing more than 900 g in polyethylene film had the same storage duration as in the stretch film – 90 days. However, natural weight loss was 1% less – 7.8%.

DISCUSSION

The results of the experiment indicate a substantial influence of the mass of the napa cabbage head on the amount of natural mass loss and the duration of storage. Similar data were obtained by L.M. Pusik *et al.* (2022) when examining the influence of the mass of carrot root vegetables on the amount of natural loss during storage. The largest root crops were characterised by gradual, without sharp fluctuations, and the smallest natural mass loss during the entire storage period. The studies by L. Pusik *et al.* (2022) identified that the duration of storage of large carrot roots increases by 46 days and is 206 days. The yield of marketable products of small carrots is reduced by 9% (Pusik *et al.*, 2022). In the paper of I.K. Arah *et al.* (2016), it is noted that the preservation of vegetable products depends on post-harvest refinement: sorting by quality and calibration by the size of the food body. V.A. Koltunov & L.M. Pusik (2007) identified that at a daytime temperature of 26-30°C zucchini fruits with a diameter of more than 8 cm are stored for 7-16 days longer than those of 4.5-6.0 cm in diameter. At a temperature of 5±1°C, the shelf life is extended to 13-21 days. It was identified that the loss of fruit mass during storage at a temperature of 5±1°C is 42% dependent on their size. The yield of marketable products depends on the size of the fruit by 22%.

Similar studies were conducted on the storage of cucumbers of different lengths. It was identified that they are stored for almost two weeks with practically no loss at a temperature of 5±1°C in boxes with plastic wrap or in plastic bags with a capacity of 20 kg. The average daily loss of fruits, when stored in plastic bags, did not exceed 0.08-0.10% (Koltunov *et al.,* 2006).

Various means are used to extend the period of consumption of fruit and vegetable products, but the most affordable of them are synthetic films for packaging. The film creates a protective coating under which a modified gas environment is formed, which prevents the development of microorganisms on the surface of the product. Furthermore, W. Hu *et al.* (2007) identified that storing various types of cabbage in bags made of perforated film allows them to better preserve their appearance, taste, and ascorbic acid content. There is a lot of information about the successful use of an edible protective coating for the same purpose, but, for example, R.K. Dhall (2013) notes that the use of an edible protective coating to preserve fruits and vegetables is not always justified. Antimicrobial treatment and washing of products to clean and disinfect their surface also do not always justify themselves. Washing, both with ordinary water and with the addition of, for example, citric acid and ascorbic acid, chlorine, and treatment with ethanol, removed from the surface of the product parts of spores of pathogenic microorganisms and exudates that can be used as a nutrient medium for them. But this did not help to increase the shelf life of products that have delicate integumentary tissues, for example, microgreens. In addition, it leads to the development of microbes that are resistant to these substances. Turner *et al.* (2020) noted that the washing and drying technology is still imperfect. Therefore, the authors recommend using plastic packaging, which helps create a passive modified gas atmosphere, to extend the preservation of microgreens.

The morphological structure of napa cabbage heads makes the technology of washing and drying it impractical. Thus, the use of synthetic films is also a universal measure for preserving fruit and vegetable products. Thus, M. Choudhary & R.A. Devi (2021) note the positive effect of polymer films as the packaging on the preservation of colour, texture, and presentation of broccoli heads. When storing napa cabbage in a polypropylene film with different types of perforation at a temperature of 10°C within 10 days, B.M. Mampholo (2013) noted the preservation of the overall quality of the heads. A study of the storage of napa cabbage at temperatures of 4, 8, and 10°C was conducted by Shim *et al.* (2016). There are findings for storing napa cabbage at room temperature in a passive modified gas environment using multicomponent films: with a high transmission rate of water vapour and a film with a high transmission rate of oxygen (Yang *et al.,* 2018). Unfortunately, there are few studies on the complex influence of various factors on the preservation of napa cabbage, they are disparate and generalised.

E.F. Balan *et al.* (2007) identified that the rate of loss reduction during cabbage storage varies. During the transition to a state of rest, vital processes, especially respiration, are inhibited. During the preparation for germination and in the process of germination of vegetable growth points (seeds, buds, eyes), the intensity of respiration increases. After that, there is a sharp decline in all vital processes. An increase in the intensity of respiration during the last storage period is associated with the formation of meristematic tissues with cells that have a larger number of mitochondria. Energy is needed for the biosynthesis of substances and the formation of new tissues, which explains the increase in the intensity of respiration at the end of storage.

A similar trend is observed during the storage of napa cabbage. Daily weight loss in the first 10 days ranged from 0.1% when storing heads in packaging to 0.61% in open form, in the middle of the storage period (50 days), daily loss increased to 0.5-1.6%, and at the end of storage 0.11-0.12%.

Based on the above, the research on the shelf life of napa cabbage, depending on the type of packaging and the size of the head, is relevant. Examining the dynamics of cabbage weight loss will allow for determining the duration of storage of heads with minimal weight loss and deterioration of quality. Weight loss of fruit and vegetable products is a function of many arguments. The definition of this indicator is of great scientific and practical importance. Knowing and regulating the factors that affect the weight loss of napa cabbage heads during storage can substantially decrease it.

CONCLUSIONS

Napa cabbage in boxes without packaging can be stored for 20 days, but with substantial natural weight loss of up to 10.6%. It was identified that the method of packaging napa cabbage heads affects the natural weight loss and shelf life. Individual packaging in a stretch film with a thickness of 8 microns reduces the natural weight loss of napa cabbage by almost two times, embedded in a container made of 40 microns plastic film, by six-eight times compared to storage without packaging. The use of polymer film packaging extends its storage period to 90 days.

The shelf life of napa cabbage depends on the mass of heads. Heads weighing 350-900 g were packed in stretch film and stored for 70 days with a natural weight loss of 10.8-10.6%. Polyethylene film extended the shelf life of heads weighing 350-700 g by 10 days – weight loss was 10.1%; heads weighing 750-900 g were stored for 20 days longer – weight loss was 10.0%. The mix of heads in the stretch film was stored for 80 days with a weight loss of 10.2%, and in those in polyethylene film – for 10 days longer with a loss of 10.0%.

Packing the head (more than 950 G) in a film provided a storage duration of up to 90 days. Natural mass loss in stretch film reached 8.8% and in polyethylene film with a thickness of 40 microns – 7.8%. Studies have shown that the density of napa cabbage heads ranges from 1.14 in Suprin F_1 hybrid up to 1.36 – in Bilko F_1. The head mass loss during storage is closely related to the head density (r=0.9746). The density of cabbage depends on the content of dry soluble substances (r=0.9786). Among the examined hybrids, Bilko F_1 has the best keeping properties, containing dry (6.4%) and dry solutes (5.1%), vitamin C (50.5 mg/100 g) and total sugar (2.9%).

Prospects for further research are possible with the improvement of elements of post-harvest refinement of cabbage. The possibilities of using edible films, coatings with antimicrobial properties have improved the concept of active packaging, they are designed to reduce, inhibit, or stop the growth of microorganisms on food surfaces. The results of the study can be used directly by manufacturers and representatives of the retail sector to extend the shelf life of fresh products.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Дослідження втрати маси капусти пекінської залежно від виду пакування та маси головки

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Анотація. Подовження періоду споживання свіжої капусти пекінської з різною масою головки за рахунок використання полімерних плівок є актуальним. Метою роботи було експериментальне обґрунтування заходів подовження строків споживання капусти пекінської. Продукцію вирощували і зберігали у фермерському господарстві. Дослідження з головками капусти пекінської проводили з використанням лабораторного методу і методу математичної статистики. Встановлено, що капуста пекінська під час зберігання втрачає до 10 % маси за 20 діб зберігання. Індивідуальне пакування головок у стретч-плівку, порівняно зі зберіганням у відкритому вигляді, дозволило зменшити природні втрати їх маси у два рази, збільшити період зберігання до 90 діб. Серед досліджуваних гібридів кращі лежкоздатні властивості були у гібрида, що характеризувався більшим вмістом сухих і сухих розчинних речовин, вітаміну С та загального цукру. При дослідженні лежкоздатності капусти пекінської залежно від маси головки встановлено, що стретч-плівка подовжує тривалість зберігання головок масою 350-700 і 750-900 г до 70 діб. Природні втрати маси при цьому сягають 10,8 %. Головки масою більше 900 г за такого пакування зберігаються 90 діб із природними втратами 8,8 %. Вкладні з поліетиленової плівки завтовшки 40 мкм подовжили тривалість зберігання головок капусти масою 350-700 г до 80 діб із втратами маси 10,1 %. Головки масою 750-900 і більше 900 г зберігалися 90 діб із природними втратами маси відповідно 10 і 7,8 %. Зберігання суміші різних за масою головок капусти пекінської у стретч-плівці збільшило період зберігання до 80 діб, а у поліетиленовій плівці – до 90 діб із втратами маси близько 10 %. Дані результати можуть бути використані науковцями в представниками торговельній галузі з метою подовження періоду зберігання плодів та овочів

Ключові слова: свіжа капуста; фракції головок; стретч-плівка; поліетиленова плівка; тривалість зберігання